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VOL I

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N66/16695

ANALYSIS OF POTENTIAL SECONDARY EXPERIMENTS FOR A SOLAR-THERMIONIC FLIGHT TEST VEHICLE

Prepared for

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Jet Propulsion Laboratory
4800 Oak Grove Drive
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Attention: Mr. J. L. Flatley

Contract No. 951162

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Volume I — Summary

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ELECTRO-OPTICAL SYSTEMS, INC. - PASADENA, CALIFORNIA
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FOREWORD

This is the final study report covering the work accomplished from 14 May 1965 to 15 October 1965 by Electro-Optical Systems, Inc., for the Jet Propulsion Laboratory under Contract No. 951162. Engineers and scientists throughout EOS made contributions to this study and the principal contributors are identified at the beginning of each volume. Also, several references and technical sources were used as technical and background information. These are identified at the end of each section.

Mr. R. Boring provided technical direction of the program for the Jet Propulsion Laboratory.

The study report is divided into four volumes.

Volume I	Summary
Volume II	Science Experiments Catalog
Volume III	Engineering Experiments Catalog
Volume IV	Spacecraft/Experiment Payloads

N66-16695

ABSTRACT

This report contains a catalog of representative ancillary experiments of a scientific and engineering nature suitable for inclusion on experimental spacecraft designed by General Electric Company under JPL Contract No. 950852. The experiment catalog is divided into the appropriate scientific disciplines and engineering technologies. The study includes consideration of the mission and spacecraft factors affecting the selection of experiments. Consideration is also given to the scientific merit, the practical merit, compatibility, and engineering value in the selection of the experiments contained in the catalog. These considerations, as well as the experimental spacecraft constraints are used to develop representative experiment payloads for three different specified missions. The details of the experiment payloads and the interface with the various spacecraft subsystems are discussed and summarized. The results of this study indicate that the JPL experimental spacecraft offers a flexible "bus" and mission concept on which many scientific and engineering experiments can be conducted.

author

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1. INTRODUCTION

The primary objectives of the study program described in this report were to prepare a summary catalog of experiments of a scientific and engineering nature for an experimental flight vehicle and to develop representative experimental payloads for three specified missions using the generated experiment catalog and the JPL experimental spacecraft constraints.

The study plan to accomplish these objectives started with defining the missions from the point of view of scientific and engineering experimenter interest, then spacecraft interfaces and constraints were defined for the experiments. Based on this preliminary information, a list of scientific and engineering experiments was prepared. This preliminary list was evaluated against selection criteria and reduced to a total of 66 experiments, composed of 33 scientific experiments and 33 engineering experiments. This final list of experiments was expanded in the form of detailed writeups into a short catalog.

The results of the experiment catalog and spacecraft constraints were then used to establish the representative experiment payloads for each of the three missions of interest.

During the study, it became apparent that a definite need exists for an engineering technology-oriented spacecraft similar to the one studied in this report. The scientist has the OGO, OAO and OSO satellites available on which to perform experiments. The engineer is still faced with the problem of "space proven" hardware and at the present time has little opportunity to "space prove" new concepts. With a highly flexible "bus" concept, the engineer would have a mechanism to verify hardware operation.

1.1 Ground Rules

The major ground rules for this study are summarized as follows:

1. Three basic types of orbits were specified:

   a. Mission A - one thousand (1000) nautical mile modified sun synchronous

   b. Mission B - two hundred (200) nautical mile perigee and twenty-five thousand (25,000) nautical mile elliptical orbit of high light-to-shadow ratio

   c. Mission C - circular orbit 325 nautical miles

   The orbits are defined in more detail in Subsection 1.2.

2. The experimental spacecraft configuration is specified in the final report on JPL Contract No. 950852, dated 1 May 1965. The spacecraft will be as specified in the JPL/GE report with no modification. The specified spacecraft/experiment interfaces are defined in more detail in Subsection 1.3. A conceptual sketch of the spacecraft is illustrated in Fig. 1.

3. The experiments are based on present state-of-the-art capabilities. Where a specific instrument is not available, state-of-the-art technology was used.

4. The selected experiments should provide information of interest to the scientific and engineering community.

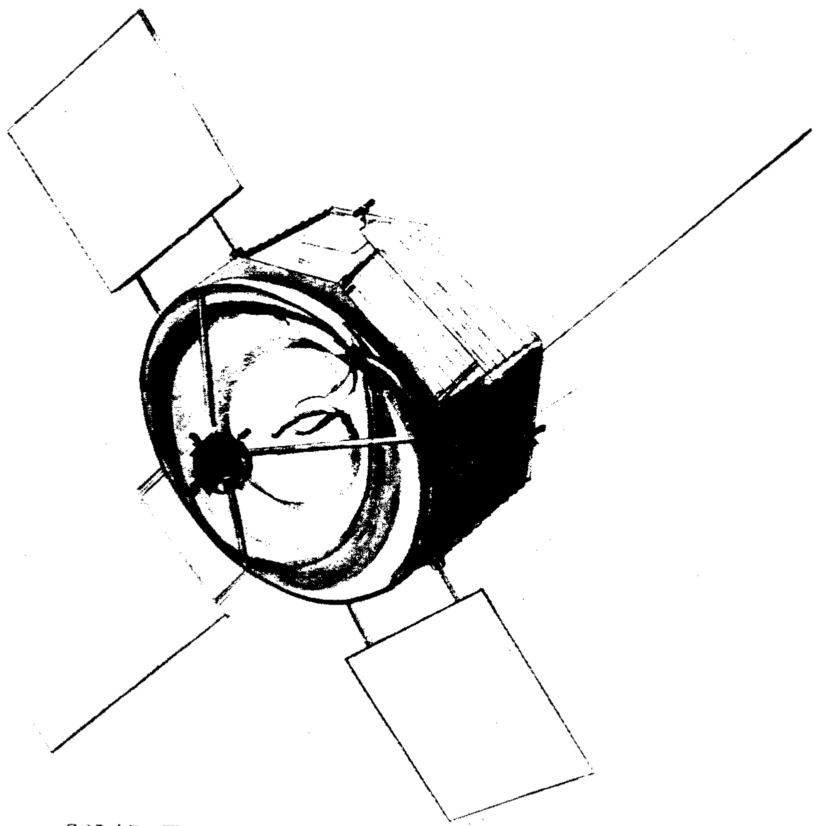


FIG. 1 SPACECRAFT CHARACTERISTICS AFFECTING EXPERIMENT SELECTION

2. CHARACTERISTICS OF ORBITS AND MISSIONS

Three missions are defined and are designated as Missions A, B, and C. Their primary characteristics are summarized in Table I. A major difference between the selected missions is the orbit, conceptually illustrated in Fig. 2. Some minor spacecraft component changes are made for the different missions, but the basic spacecraft is the same and a version of the improved Delta launch vehicle is used in all three cases. The solar-thermionic experiment design (primary experiment) is identical for each of the missions. The secondary experiments included on board the spacecraft will vary between missions because of the different orbits employed. The JPL design offers the advantage of allowing the different missions to be flown with the same basic spacecraft, thus increasing the program flexibility and reducing the cost if more than one of the missions is undertaken.

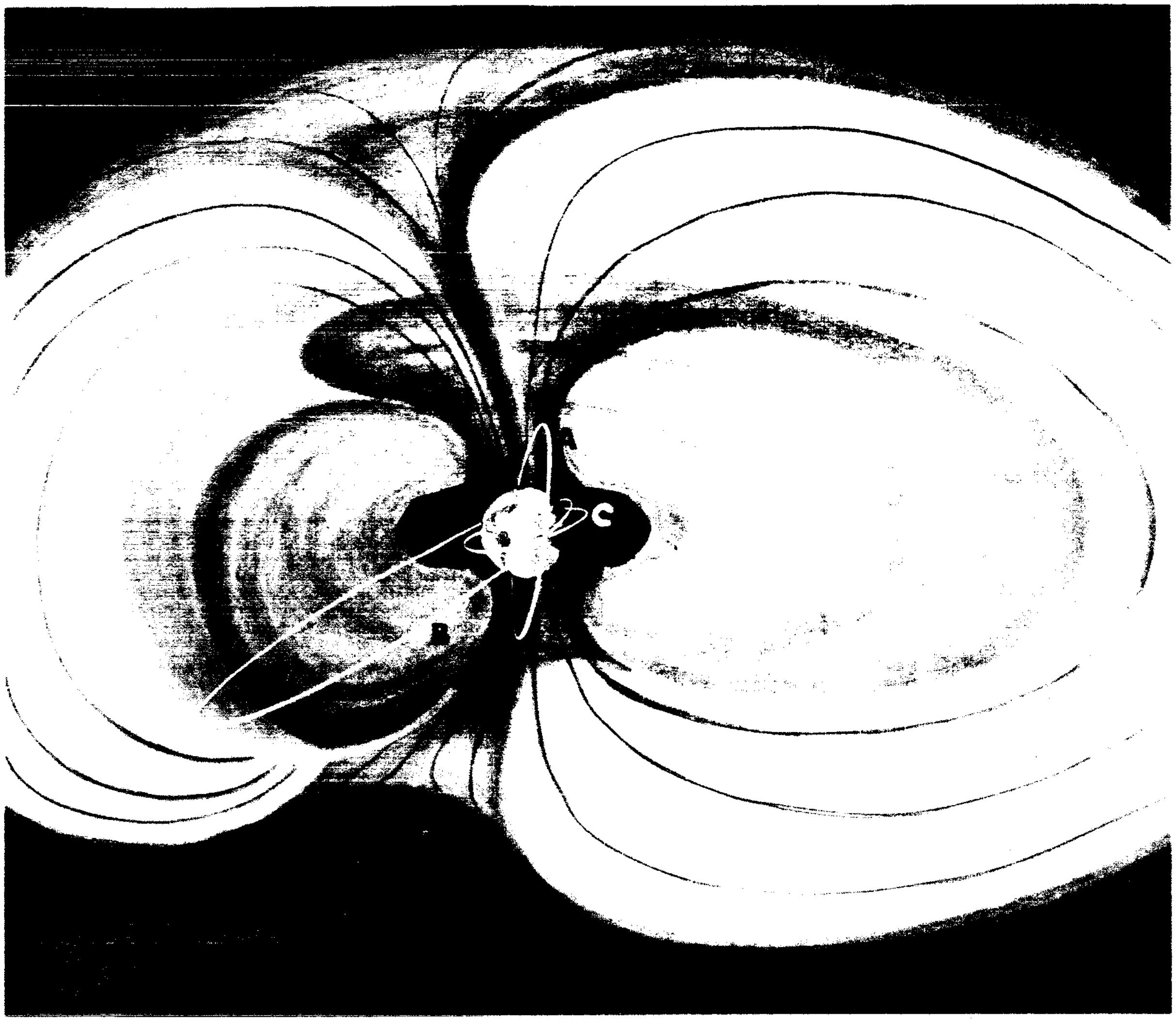
The characteristics of the various orbits are shown in Fig. 2 and summarized in Table II.

TABLE I

SUMMARY OF MISSION PARAMETERS

Parameter	Mission A	Mission B	Mission C
Type of Orbit	Modified Sun-Synchronous	Highly Elliptical	Low Altitude Circular
Orbit Altitude, Nautical Miles	1000	25,000 apogee 200 perigee	325
Orbit Inclination, Degrees	101.84	45	30
Orbit Period, Hours	2.07	14.0	1.61
Orbit Maximum Dark Period, Hours	0.4	2.09	0.617
Launch Vehicle	IMPROVED DELTA DSV-3E	IMPROVED DELTA DSV-3E[(a)]	IMPROVED DELTA DSV-3H
Launch Site	WTR	ETR	ETR
Thermionic System Concentrator Diameter, Inches	50	50	50
Thermionic Generator Power Output, Watts	144	144	144
Thermionic System Efficiency, Percent	8.2	8.2	8.2
Spacecraft Weight, Pounds	360	373	404

(a) - First Stage Floxed 30 Percent



MISSION FEATURES

A. VAN ALLEN INNER BELT
AURORA EFFECTS
LONG LOOK AT SUN

B. TRAVERSE HIGH-INTENSITY VAN ALLEN
ATMOSPHERIC CROSS SECTION

C. BELOW VAN ALLEN
NEAR-EARTH OBSERVATIONS

ALL MISSIONS HAVE INTEGRATED ENVIRONMENT. TEMPERATURE, PRESSURE, MICRO-METEOROIDS, ELECTROMAG. RAD. "UV", MAGNETIC FIELDS, CHARGED PARTICLES, AND ZERO GRAVITY

FIG. 2 SPECIFIED MISSIONS

TABLE II

EXPERIMENT VALUE FOR VARIOUS ORBITS

Orbit	Experiment Value
Mission A Modified Sun Synchronous (1000 Nautical Mile)	a. Long uninterrupted look at sun b. High inclination orbit allows observation of upper latitude phenomena c. Traverses Van Allen inner belt d. Long uninterrupted look at plane of ecliptic away from sun e. Polar cross section of Earth's magnetic field and associated effects f. Integrated environment of space
Mission B Highly Elliptical Orbit (200 by 25,000 Nautical Mile)	a. Traverses inner and outer radiation belts from minimum to maximum values b. Traverses Earth's upper atmosphere c. High sun-to-dark ratio d. Perigee allows near-Earth observations e. Inclined cross section of Earth's magnetic field and associated effects f. Integrated environment of space
Mission C Low Altitude Circular (325 Nautical Mile)	a. Below inner Van Allen b. Near Earth observations c. Integrated environment of space

3. CHARACTERISTICS OF THE EXPERIMENTAL SPACECRAFT

The basic JPL experimental spacecraft is shown in Fig. 3 with all the secondary experiments removed. This same basic spacecraft design is used for Missions A, B, and C with minor component changes required between missions.

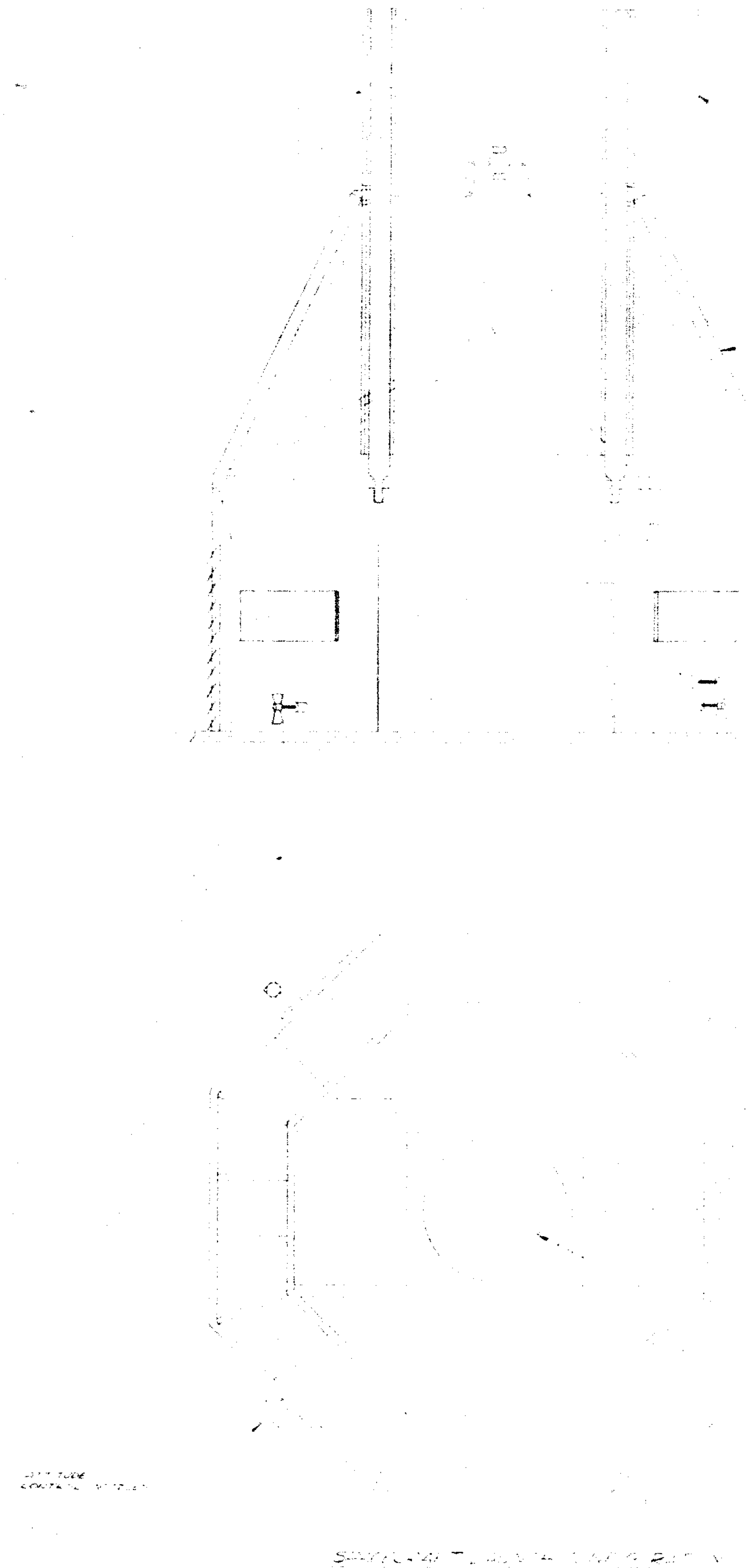
The basic system consists of two parts, the experiments and the spacecraft. The spacecraft consists of a structure to support and protect the experiments and other assemblies, an attitude stabilization subsystem, power, data handling, communications, and thermal control subsystems for servicing the experiments. The weight of the spacecraft is approximately 240 to 280 pounds, and it is designed to accommodate about 38 pounds of primary experiments and approximately 85 pounds of secondary experiments, making a total spacecraft weight of about 360 to 400 pounds. The resulting weight totals are:

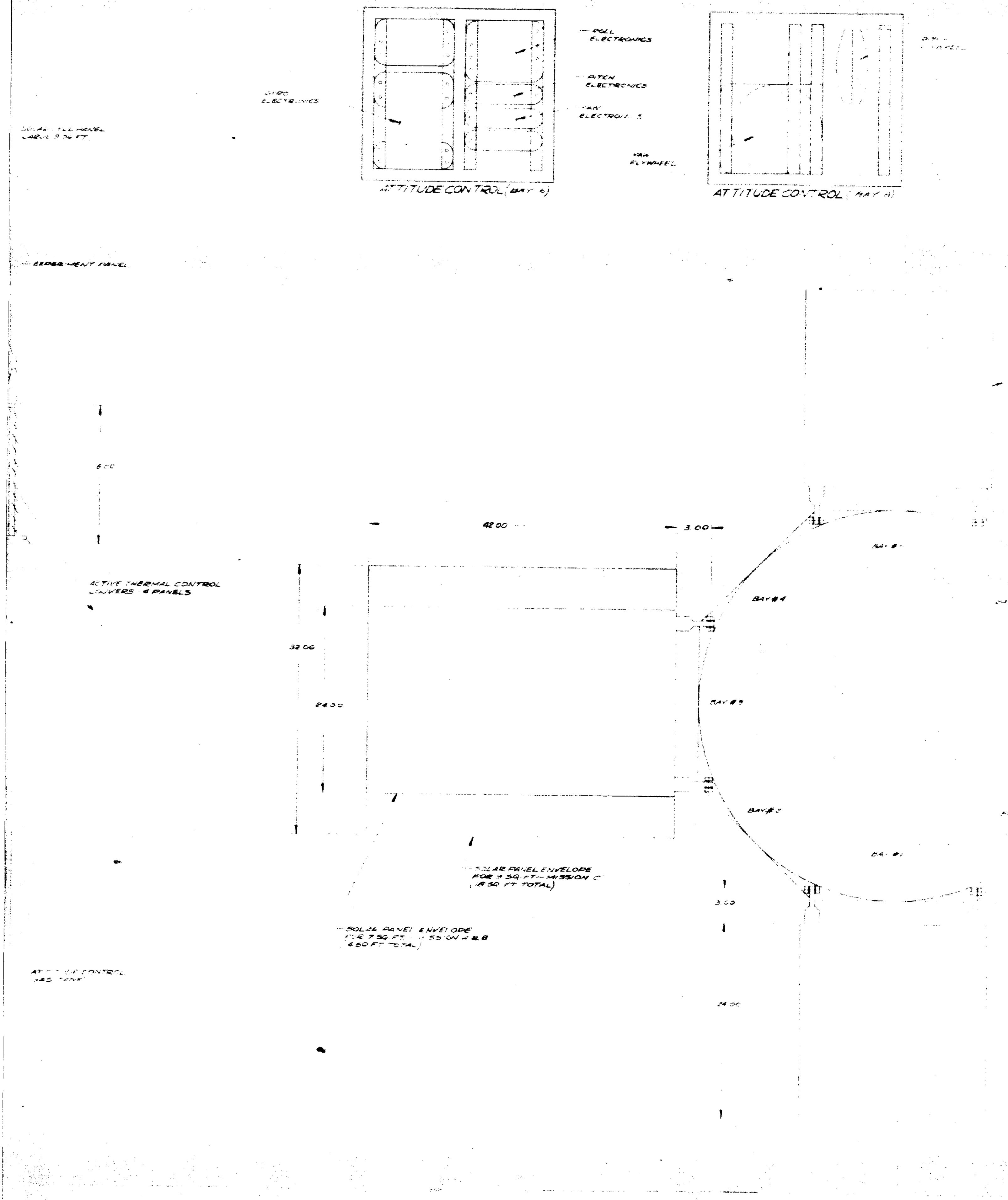
Total system weight, Mission A - 360 pounds

Total system weight, Mission B - 373 pounds

Total system weight, Mission C - 404 pounds

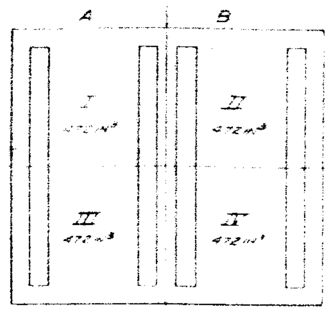
To maximize the experiment weight capabilities for the various missions and launch vehicle capabilities, some subsystem weights have been modified for specific missions. The differences in the total spacecraft weights result primarily from a difference in the attitude control and power subsystem weights. The remaining subsystems and experiments weigh approximately the same for all three missions. The power subsystem weight increases from Missions A through C because the light-to-shadow ratio becomes progressively worse. The unfavorable light-to-shadow ratio results in a secondary battery weight which for Missions B and C is more than twice that for Mission A. The attitude control subsystem weight is approximately ten pounds higher for Mission C than for Missions A and B, because of the additional gas required for the pneumatic system. The



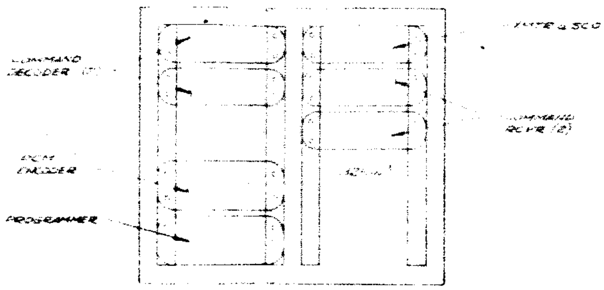


ROLL ELECTRONICS
PITCH ELECTRONICS
YAW FLYWHEEL
ATTITUDE CONTROL
ATTITUDE CONTROL
42.00
3.00
32.00
24.00
ACTIVE THERMAL CONTROL
BAY #4
BAY #2
SOLAR PANEL ENVELOPE
SOLAR PANEL ENVELOPE
3.00

#2



EXPERIMENT ELECTRONICS (BAY 5)



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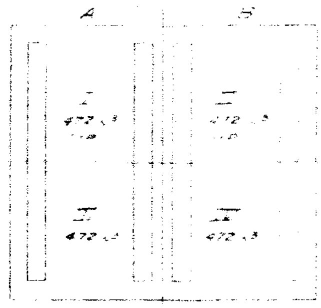
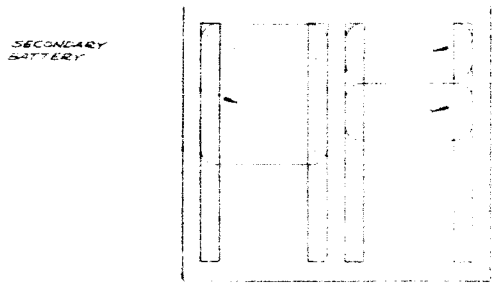
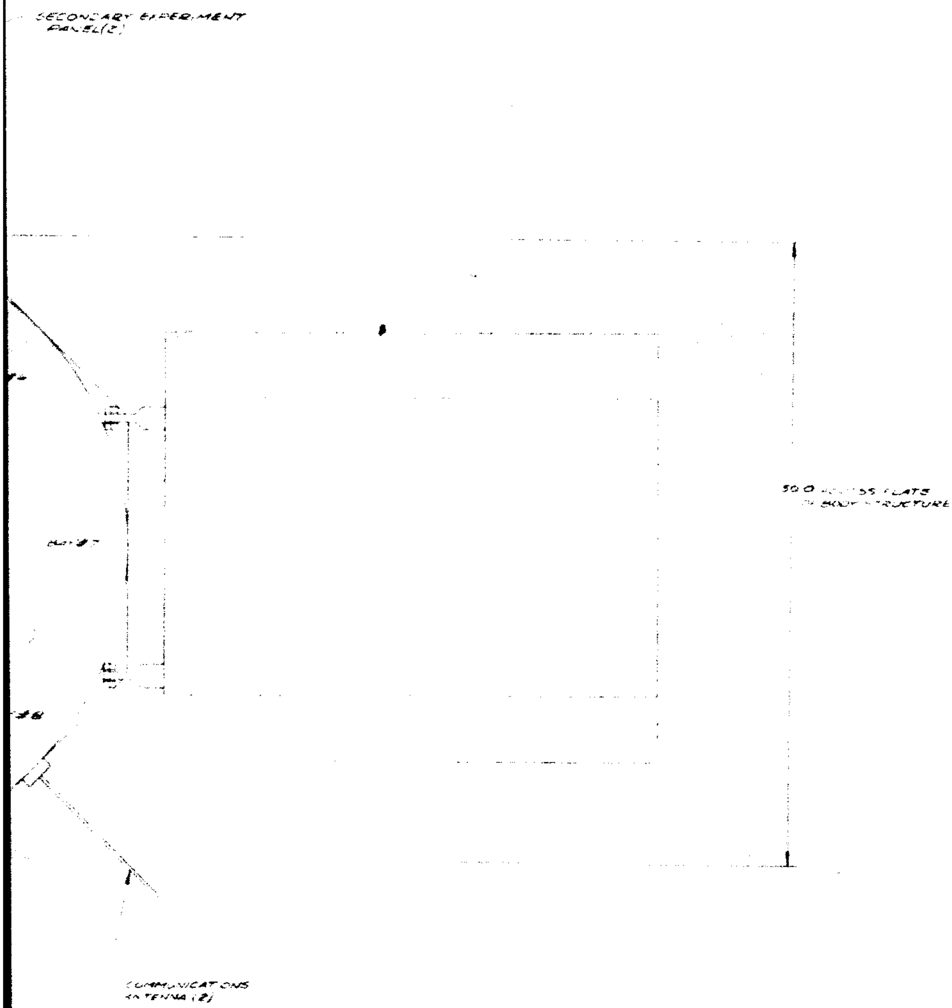


EXPERIMENT ELECTRONICS (BAY 2)



POWER SUBSYSTEM



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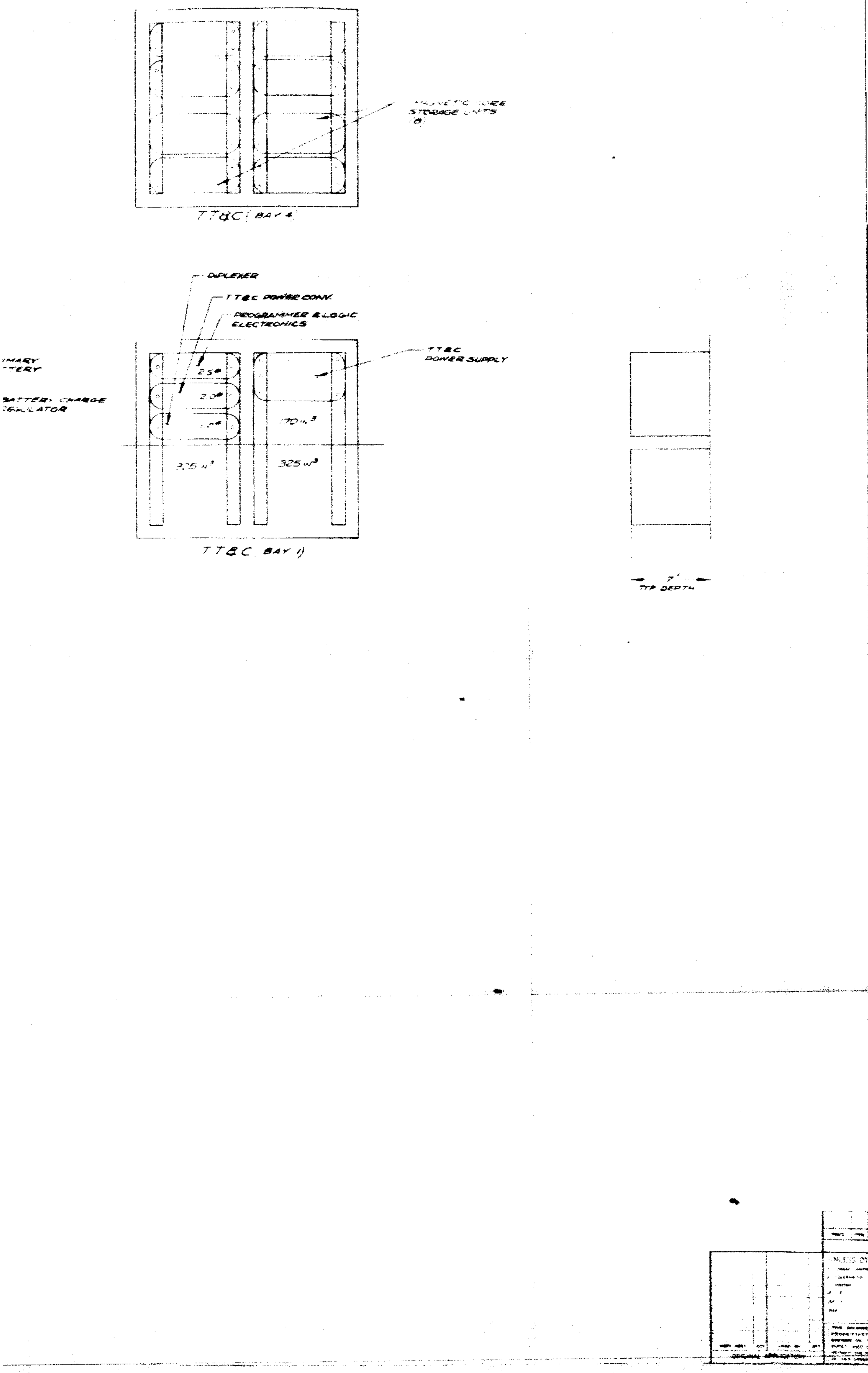

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FIG 3 SPACECRA

REVISIONS

LIST OF MATERIALS

...ERWISE NOTED

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TITLE SPACECRAFT CONFIGURATION

12705

SCALE NONE

...FT CONFIGURATION #5

higher gas requirement occurs because the low altitude of the Mission C orbit results in significantly higher gravity gradient disturbance torques.

A common experiment on board the spacecraft is a solar thermionics experiment, but the capabilities of the data handling, power, attitude control, and thermal subsystems allow great flexibility in accommodating secondary experiments. The spacecraft design is such that it presents a well-defined set of interfaces to the experiments.

The spacecraft design can be used repeatedly, with only minor modifications, for different combinations of experiments. Some of the advantages of using a basic spacecraft which can accommodate a variety of experiments are:

1. Large numbers of directly and indirectly related experiments can be performed concurrently to study the correlations between several phenomena at given positions in space.
2. The system reliability should be improved ultimately by the repeated use and continuous improvement of the basic spacecraft.
3. The electrical, mechanical, and thermal interfaces between the experiments and spacecraft subsystems are well-defined and will remain essentially fixed from mission to mission.
4. The continued use of a standard spacecraft design should lead to higher operating efficiency through the continuous evolution of a ground data acquisition and tracking station network, data processing equipment, and operating procedures.

A brief description of the actual spacecraft configuration and the major subsystem features pertinent to the experiments is discussed in the following sections. A summary of the spacecraft requirements and constraints on experiments is given in Table III.

3.1 Configuration

The spacecraft body is an eight-sided prism with flat ends. The components are mounted in a modular fashion in the eight equipment

TABLE III

SPACECRAFT REQUIREMENTS AND CONSTRAINTS ON EXPERIMENTS

CONFIGURATION:

Spin Balance ~ 0.015 inch centerline - static
0.002 radian - dynamic
Experiment Total Weight - 80 to 85 pounds
Maximum Volume
Equipment Bays 2(1.5'x1.5'x0.5') = 2.3 cubic ft
Secondary Panels 2(2'x2'x1') = 8 cubic ft
Temperature
Inside Bays $5^{\circ}C$ to $35^{\circ}C$
Outside Bays $-10^{\circ}C$ to $+50^{\circ}C$
Mounting
Equipment Bays - Standard Module (10"x6"x18" max.)
Secondary Panels - Custom Fit
Field of View
4 Bay Panels ~ 90°
4 Bay Panels Obscured
Bottom Panels ~ 180°
Secondary Panels ~ 180°
Power Subsystem
Voltage Range
+27 to +33 volt unregulated
High Line Noise
Provide Own Regulation
Total Experiment Power
Day ~20 watts
Night ~ 7 watts
Continuous Day ~30 watts
Attitude Control
Sun Lock
Pitch ~ $\pm$ 0.07 degrees
Yaw ~ $\pm$ 0.07 degrees
Gyro Lock
Pitch ~ $\pm$ 0.2 degrees
Yaw ~ $\pm$ 0.2 degrees
Roll Rate
~ 10 degrees/hour
Gas expulsion limited
Data Handling & Telemetry
Analog 0 +5 volts
Digital
Storage Capacity - Experiments
Mission A < 102,000 bits/orbit
Mission B < 420,000 bits/orbit
Mission C < 70,000 bits/orbit

TABLE III (contd)

SPACECRAFT REQUIREMENTS AND CONSTRAINTS ON EXPERIMENTS

Command Subsystem
 30 on-off commands
 For experiments
 Remote sequencing
Tracking Subsystem
 UHF R&RR accuracy
  $\pm$ 0.1 degree pointing
  $\pm$ 15 meters range
 136 Mc
Solar Thermionics
 Nickel Mirror
 Magnetic Field 2-3 gauss

bays (see Fig. 3). Bays No. 5 and 2 are exclusively for secondary experiments. Experiments mounted in these bays will be packaged in a standard module which is 10 inches wide, 6 inches deep and a maximum of 18 inches high. Four of the eight spacecraft sides have active thermal control and are not available for mounting or viewing ports for experiments. The remaining four sides are used for mounting the attitude control nozzles, the telemetry antenna and experiment hardware and are available for experiment viewing ports.

The lower octagonal face and center internal volume may be used for mounting experiments and sensors which must look away from the sun. The upper octagonal face is used for mounting the solar thermionic experiment, which does not leave room for sun-oriented experiments on this face. Four deployable panels are hinged off this upper face, the two large panels are used for photovoltaic power and the two smaller panels are sun-oriented and used for secondary experiments.

3.2 Thermal Control

The temperature control system is essentially the same as the Mariner C spacecraft. The excess heat rejected is controlled by variable louvers attached to the outside of the four controlled panels. In addition to the active thermal control system, thermal balance is maintained by super insulation and coatings on the other exposed surfaces.

Thermal control of the temperature of equipment mounted outside the bays is achieved passively by the use of thermal coatings (auxiliary heater power may be used in special cases).

The nominal temperature excursions to be experienced by the experiments with a spacecraft thermal design as specified above are summarized in Table III.

The thermal control subsystem preliminary design indicates the temperatures of all the assemblies in the main body of the spacecraft be controlled within the limits of 5° and 35°C. Since the satellite may spend periods as long as 2 hours in the Earth's shadow, it is necessary to use an active thermal control system. The use of an active system also makes it easier to accommodate large variations in experiment power dissipation and allows various sizes of experiment sensor openings through the external surfaces.

Thermal input to the spacecraft from the sun is reduced to a very low value by an efficient radiation shield (solar thermionic mirror), and the thermal radiation from the body is controlled by variable-area radiation panels and passive radiation shields. A radiation shield, consisting of multiple layers of aluminized Mylar, covers the four sides which are not actively thermal-controlled and the end of the main body. The four other sides are covered with thermal insulation louvers to control their exposure. Each louver is positioned by a bimetallic spring which senses the temperature of the radiating panel. When the temperature of the radiating panels rise, the louvers open to allow the radiation of more heat.

Thermal control of the appendage experiment assemblies is obtained by using thermal radiation shields, radiation surfaces, and electrical heating. The radiation area sizes and locations will be chosen to provide a proper heat balance during periods of maximum energy input. Electrical heaters can be provided to supply additional energy during long eclipses or when the experiment power is turned off. With this system, the temperatures of the experimented assemblies within the appendage assemblies normally will be between -10° and $50^{\circ}C$.

Experiment sensors that protrude through the radiation barriers on either the main body or the appendage containers present special thermal problems. They must be designed so that the solar energy flux, about 1400 W/m^2 if exposed to the sun, does not cause excessive heating of the sensors, and so that the thermal radiation, when the sensors are not illuminated by the sun, does not cause excessive cooling. In some cases it is necessary to allow greater temperature excursions than those quoted above for sensors having large openings.

3.3 Solar Thermionic Experiment

The primary interface of the experiments and the solar thermionic experiment is the magnetic field considerations. Assuming the concentrator is made of nickel and is first demagnetized and prevented from further magnetization by avoiding close proximity to strong magnetic fields, the lower limit of magnetic field the concentrator would assume is set by the Earth's magnetic field at sea level. This value at the worst is approximately 1 to 2 gauss. Any experiments sensitive to a magnetic environment of this magnitude should provide isolation from the concentrator. It should be noted that over 100 watts of power will be available from the solar thermionic experiment - this power could be used for those experiments demanding large amounts of power such as thermal heaters, etc.

3.4 Spacecraft Power Subsystem

The primary power for the total spacecraft is furnished by the photovoltaic subsystem; the solar thermionic power is strictly utilized as an experiment and not functional for general power usage.

The secondary power subsystem is a nickel cadmium battery pack with supplies the power requirements when the spacecraft is in the Earth's shadow or when transient loads exceed the photovoltaic capabilities.

The battery provides coarse regulation of the main bus, the bus voltage will vary between the battery charge (+ 33.5 volts) and the discharge (+ 27.5 volts) values. The experiments which require better regulation than this will provide their own power conditioning and control. Provision should also be made against electrical transients and high level noise on the power bus lines due to other experiments and spacecraft subsystem interactions on the power subsystem.

A power control unit provides switching of the power to the experiments according to ground commands and/or programmed basis.

The power budget allocated for the secondary experiments for the various missions is summarized in Table IV.

3.5 Attitude Control Subsystem

The solar thermionic system necessitates an orientation accuracy of ±0.1 degree about the pitch and yaw axis. There is no position control about the roll axis but the vehicle roll rates are limited to avoid gyroscopic cross-coupling problems. Since the solar thermionics is rigidly

TABLE IV

POWER ALLOTMENT FOR SECONDARY EXPERIMENTS

	Mission A 1000 n. mi.	Mission B 200-25,000 n. mi.	Mission C 325 n. mi.
Day-Night Operation			
Day			
Power	~ 18 watts	15 watts	23 watts
Voltage	~ 27.5 volts	~ 27.5 volts	~ 27.5 volts
Current	~ 0.65 amp	~ 0.54 amp	0.82 amp
Night			
Power	7 watts	6.5 watts	7 watts
Voltage	~ 27.5 volts	~ 27.5 volts	~ 27.5 volts
Current	~ 0.25 amp	~ 0.23 amp	~ 0.25 amp
Continuous Day Operation*			
Power	~ 30 watts	~ 27 watts	N/A
Voltage	~ 27.5 volts	~ 27.5 volts	N/A
Current	~ 1.1 amp	~ 1.0 amp	N/A

* Assumes continuous day operation for extended period and the pitch and yaw gyros are assumed turned off with excess power available to the experiments. This mode of operation could be used for approximately six months in Mission A and approximately 70 days in Mission B, but not at all in Mission C since there are no shadow-free periods.

attached to the spacecraft body the entire spacecraft is oriented to the sun. Momentum flywheels provide the pitch and yaw fine pointing control and the expulsion of gas from the spacecraft is kept to a minimum. The control and accuracies provided by the attitude control are summarized in Table III.

Provision has been made for infrared sensors to reduce the roll ambiguity, but the accuracy of the system is not defined.

3.6 Data Handling and Telemetry Subsystems

The spacecraft data handling and telemetry subsystem processes, stores, and telemeters the spacecraft experiment and housekeeping data and generates timing signals for use in the experiments and spacecraft subsystems. Two forms of data from the experiments can be accommodated: analog and digital.

The data handling capability is summarized in Table V.

TABLE V

SPACECRAFT DATA HANDLING CAPABILITY

	Mission A	Mission B	Mission C
Ancillary Experiment	< 102,000 bits/orbit	< 420,000 bits/orbit	< 70,000 bits/orbit
Total Data Storage	< 240,000 bits/orbit	< 800,000 bits/orbit	< 150,000 bits/orbit
Playback Rate	400 bits/sec	3,340 bits/sec	1,250 bits/sec
Playback Time	10 min	4 min	2 min
Coding Method	PCM/FM/PM	PCM/FM	PCM/FM/PM

The accuracy of the reading of the experiments is proportional to the number of bits used for coding the signal. The coding accuracies are summarized in Table VI.

TABLE VI

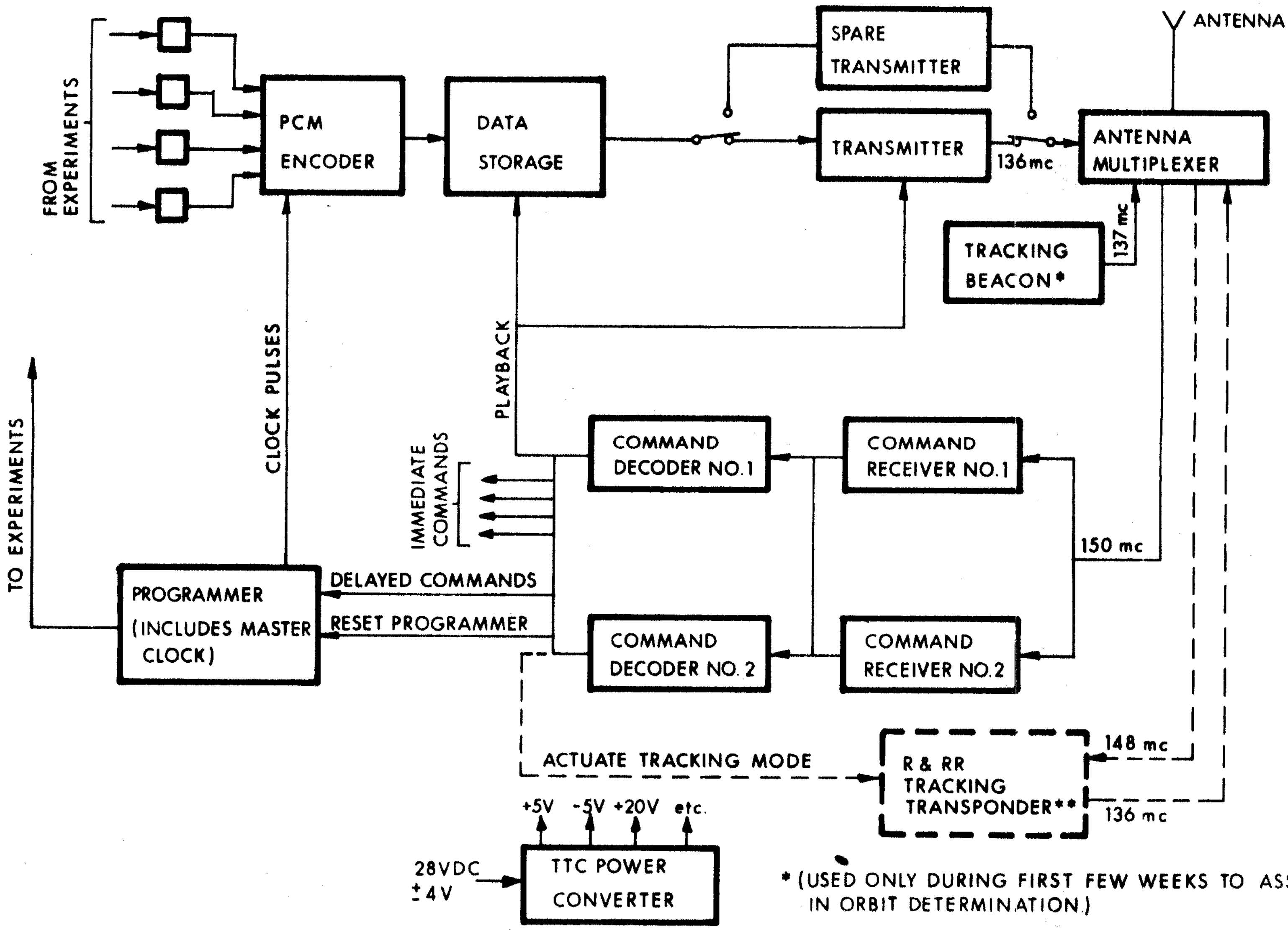
SPACECRAFT CODING ACCURACIES

Number of Binary Digits N	Quantization Accuracy
5	±1.5%
6	±0.8%
7	±0.4%
8	±0.2%

Therefore, experiments requiring a ±1.0 percent accuracy require a six bit coding.

The spacecraft data handling and telemetry subsystem is designed to process, store, and telemeter experiment and spacecraft data, and to generate timing signals for use by the experiments and the spacecraft subsystems. The major elements of the subsystem are shown in Fig. 4. It is a high-capacity digital and analog system designed to condition, multiplex, store, and transmit data from the experiments and spacecraft subsystems to the ground receiving stations. Its design provides that the simplest practicable interface exist betwee the experiments and the data system. An additional advantage is the fact that the data system design can accommodate a wide variety of experiments. Two forms of data from experiments can be accommodated, time-division-multiplexed analog data to the analog-to-digital converter and digital telemetry system, and time-division-multiplexed digital data directly to the digital telemetry system.

The interface wiring from a special purpose or analog experiment output to the data system consists of a single line and its return. The requirements are specified simply, in that the output of the experiment must remain within the 0 to 5 volt range and have a sufficiently



* (USED ONLY DURING FIRST FEW WEEKS TO ASSIST IN ORBIT DETERMINATION.)

** (HIGHLY DESIRABLE FOR ORBIT II. OPTIONAL FOR CIRCULAR ORBITS.)

low output impedance that the measuring accuracy will not be unduly affected by the input impedance of the data system.

The digital data interface allows many different types of digital experiments to be flown without modification to the data system. All signal conditioning is performed within the experiments. Two types of synchronizing lines carry signals from the data system to the experiments to control their presentation of data over the digital data output lines. One type of synchronizing line provides bit pulses; the other provides word pulses for each data input. Thus, the experimenter may divide his particular word or group of words as he desires.

Data from the experiments are sampled, digitized, stored, and telemetered by the digital data system. It consists of timing assemblies to provide timing for the experiments and all of the electronic subsystems, a patch panel to facilitate connection of the experiments to the data system, data handling assemblies for sequentially sampling all data inputs and converting analog data to binary form, tape recorders or core memories for storing the binary data, and transmitters and antennas for data transmission.

The data handling system is designed to permit flexibility in the design of experiments. Experiments whose sensors produce, basically analog signals, such as current, voltage, or resistance changes, employ signal conditioning equipment to present analog voltages in the range of 0 to 5 volts, with low source impedances, to the data system. Here they are converted to digital form. On the other hand, experiment sensors such as Geiger-Mueller counters, etc., which produce outputs that are fundamentally digital in nature, employ digital techniques to process and condition the data. The data are presented to the data system in serial binary form in synchronism with pulses obtained from the data system.

All experiment data outputs are routed to the data handling system through a patch panel. This patch panel contains terminals for all of the experiment outputs, data system inputs, and data timing signals. The telemetry format is assembled by interconnecting these terminals. The use of the patch panel provides easy initial formatting and allows last-minute changes in the format without affecting the other equipment in the spacecraft or the electrical cables.

Additional signals available to the experiments include power converter synchronization, gyro 400 cps synchronization, ground commands, and various timing frequencies. Timing pulses corresponding to the sampling times of many of the digital inputs are provided to assist the experimenters in programming the data conditioning within their experiments. To assist the experimenter in determining the data handling system operating conditions, additional signals indicate whether real time data are being transmitted, the real time bit rate, and the equipment group which is feeding the data storage system.

The digital data storage is accommodated by the magnetic core storage units or magnetic tape recorders, depending on the mission.

For the elliptical orbit, two identical redundant tape recorders store the digital data so that continuous data can be received from the spacecraft by a small number of ground stations. Each of the recorders has a storage capacity of 800,000 binary bits. The recording bit rate is either 1000 or 4000 binary bits per second, depending on the mission; thus, the recorders can record for 12 or 3 hours, respectively. The two recorders can store sequentially to provide up to either 24 or 6 hours between readouts. Readout of one recorder can occur while data are being stored on the other, to provide continuous coverage. Readout times for the two cases are 11.25 and 5.625 minutes, respectively. The recorder tapes are reversed for readout, resulting in time reversal of the data. Time reverses again during processing on the ground, returning the data to their original order.

For the two circular orbits, the orbital period is short enough that all the data collected can be stored in highly reliable magnetic core storage units.

It is a sequential access, coincident current core memory with internal addressing and counting. Its ruggedness, small size, wide temperature range, and completely solid-state magnetic drive, with no internal heating or temperature control requirements, make it quite suitable for aerospace applications. It has been fully qualified in accordance with MIL-Q-9858. Data input and output is asynchronous, one bit at a time, at any rate up to 20,000 bits per second, and the capacity is 30,096 bits per core memory unit.

Data are read out sequentially, one bit at a time, and then restored in the memory. Thus, the information stored in a particular core is erased only when that core is required for new information. After the unit has once been filled, it will always contain the last 30,096 bits received from the encoder.

The Mission A satellite would collect 240,000 bits of data each orbit and would store these in eight magnetic core storage units (20 pounds of cores). After the orbit was well established, the tracking beacon would be turned off, and the telemetry carrier activated by command (either stored or real-time) to initiate the acquisition procedure.

Acquisition should be completed in less than two minutes, and the data would be read out upon command from either the Fairbanks or the St. John's ground station at a rate of 400 bits per second for ten minutes, using PCM/FM/PM.

Orbits where neither of these ground stations had a clear line-of-sight to the satellite would be extremely rare, and the loss of data on these orbits would be accepted.

The Mission B satellite would collect 800,000 bits of data each orbit and would store these in a magnetic tape recorder. A second tape recorder would be available as a spare and to provide storage for a second orbit of data on those occasions where a ground station was not available upon completion of an orbit.

Up to two orbits of stored data would be transmitted near perigee upon command to the Mojave, St. John's, or Winkfield station at a rate of 6630 bits per second for four minutes, using PCM/FM and noncoherent reception. Frequency acquisition would not be necessary, and angular acquisition should be possible in less than one minute.

The Mission C satellite would collect 150,000 bits of data each orbit and would store up to two orbits of data in ten magnetic core storage units (25 pounds of cores).

It would be acquired in the same manner as the Mission A satellite (in about two minutes), and the data would be read out upon command from the Fort Myers, Santiago, Lima, or Quito stations at a rate of 2500 bits per second for two minutes, using PCM/FM/PM.

The digital outputs of either the data-handling equipment or the tape recorders (or core memories) are telemetered on ground by either of the transmitters. Complete command-controlled cross-strapping provisions allow the full use of the parallel redundancy to increase the reliability of the data-handling system.

One of the two digital transmitters is energized upon the receipt of a ground command. The telemetry system is automatically turned off by a timer after the loss of the command carrier. One of the transmitters feeds the omnidirectional antenna, which has a gain of -10 dB relative to isotropic radiation. The other digital transmitter is in a standby mode. It is not possible for both digital transmitters to operate simultaneously.

The digital transmitters have power outputs of 350 milliwatts to 700 milliwatts. The 136 Mc ±0.003 percent carriers are modulated by the PCM data.

The programmer provides the basic clock signals required by the PCM encoder and other units and stores and automatically executes a predetermined program of commands governing such events as separation of satellite and booster, deployment of solar panels, transmitter turn-on, etc. Back-up for some of the programmed commands can be furnished by transmitting commands from the ground. Provision should also be made to store a limited number of transmitted commands for delayed execution.

The basic timing sources are two redundant crystal oscillators with probable long-term stabilities of one part in 10^5 per year and short-term stabilities of one part in 10^6 per hour. Only one oscillator will be used at a time so that all timing is derived from a single source. Countdown circuits produce signals for synchronizing the data-handling assemblies and the tape recorders, for time reference in the experiments, and for synchronizing all power converters to minimize interference to experiments. An additional register could generate accumulated time, which can be recorded and telemetered with all digital data to serve as a basic data-time reference.

3.7 Command Subsystem

The command subsystem will provide up to 70 actuated commands. Approximately 30 of these on-off commands will be reserved initially for the secondary experiment functions.

3.8 Tracking Subsystem

A tracking subsystem is provided to establish the orbit and position of the spacecraft. The specified system uses a 136 Mc beacon transmitter in Mission A and C and a UHF range and range rate subsystem for Mission B. The accuracy of the Mission B system is capable of measurements of ±10 meters in range and ±0.1 degree in pointing angle. The accuracy of the Mission A and C R&RR are not specified. Experiments which require positional accuracy on Missions A and C should note the required tracking accuracy.

4. EXPERIMENT CATALOG

4.1 Classification

The experiments investigated in more detail have been categorized as engineering, supporting science, and science. A further breakdown into technical disciplines within the engineering and science categories is shown in Table VII, which shows the number of experiments investigated.

For purposes of this study, the experiments which are directly related to the design, operation and performance of spacecraft components and subsystems have been classified as engineering experiments. Under this definition come experiments and investigations such as solar power systems, investigation of materials seals, bearings under prolonged exposure to the extremes of space environment, attitude control investigations, thermal control experiments, reliability, space proving hardware and concepts, etc.

TABLE VII

EXPERIMENT CLASSIFICATION AND NUMBER OF SELECTED EXPERIMENTS

ENGINEERING TECHNOLOGY		SCIENCE DISCIPLINE	
Power	16	Solar Physics	10
Attitude Control	2	Stellar & Galactic Astronomy	3
Thermal	2	Atmosphere	1
Mechanical	3	Ionosphere & Radiosphere	2
Telecomm.	1	Particles & Fields	11
Optical	1	Planetology	6
Supp. Science	8	Bioscience	0
Total	33	Total	33

The engineering experiments considered in this study are representative of those that could be included on the model spacecraft. The experiments included in this section are not the only experiments possible, but the limited nature of the study precluded a complete catalog.

Under the science heading come experiments which explore atmospheric density, electron and ion density, magnetic and gravitational fields, cosmic radiation, gamma radiation, infrared and ultraviolet, astronomy, etc.

To organize the science experiments the accepted NASA science disciplines were used. These disciplines are shown in Table VIII.

4.2 Selection Criteria

It is evident that a complete examination of all possible experiments is impossible within the scope of this study. At program initiation, a list of general criteria was established against which tentative experiments were judged prior to a more detailed investigation.

Application of these criteria helped to eliminate a large number of experiments after brief examination.

4.3 Experiment List

The experiments, which are described in more detail in Volumes II and III and form the final selected catalog, are listed in Tables IX and X. The list was derived from examination of the criteria previously discussed.

It must be recognized that selection of experiments is subject to personal opinion, and that other investigators may have chosen a different group of experiments. In the science area, several of the experiments have not been allowed before and were conceived for this study.

It should also be noted that a predominant feature of the spacecraft is its solar orientation, and many of the chosen experiments take advantage of this feature.

TABLE VIII

CRITERIA USED IN EVALUATING PROPOSED EXPERIMENTS
FOR MORE DETAILED CONSIDERATION

1. Detailed Consideration Merit. Will the anticipated results of this experiment

   (a) tend to confirm or deny the validity of some scientific principle or theory? If "yes", is this theory fundamental, secondary, or peripheral in importance? Is it interdisciplinary or restricted in application?

   (b) fill an important gap in the body of knowledge concerning some phenomenon for which no satisfactory or adequate theory exists?

   (c) possibly reveal the existence of one or more previously unknown phenomena (e.g., by confirming a prediction based upon some tentative theory)?

   (d) provide more accurate and/or detailed measurements of some previously observed phenomenon?

   (e) extend the range of validity of some previously established theory or principle?

   (f) provide verification of performance (for engineering experiments) which cannot be obtained on the ground?

   (g) provide information regarding phenomena which constitute possible hazards to man (either in space or on the earth, moon, or some planet)? To spacecraft (directly, or to mission-essential components or devices)? To instruments?

   (h) verify the feasibility of some novel instrument or device by duplicating or improving measurements made with conventional instruments or techniques?

   (i) provide information of potential military value, meteorological value, or information useful in assessing the feasibility of some future experiment or mission?

TABLE VIII (Contd)

CRITERIA USED IN EVALUATING PROPOSED EXPERIMENTS FOR MORE DETAILED CONSIDERATION

2. <u>Compatibility</u>. Will the instrumentation for this experiment (ignoring telemetry and power sources)

   (a) be useful— in whole or in part— in the performance of other experiments?

   (b) produce steady or transient magnetic fields, electrostatic fields, penetrating nuclear radiations, mechanical vibrations or impulses (shocks), radiofrequency radiations, or any other effects which would interfere with other experiments or equipment on board?

   (c) require any special mounting considerations (e.g., a unique location or attitude; special thermal, magnetic, electrical, or other insulation and shielding requirements; access or viewing ports)?

   (d) require unique, extensive or complex prelaunch checkout equipment and/or procedures?

   (e) require unique, extensive or complex operational support equipment?

3. <u>Engineering Considerations</u>.

   (a) Physical (weight, volume, dimensions and shape, mounting requirements, vacuum and/or moisture sealing requirements, surface coatings and finishes, special machining of complex parts and/or to close tolerances, use of exotic materials and/or components...)

   (b) Electrical (voltage, power, duty cycle...)

   (c) Environmental (susceptibility to vibration, shock, acceleration, temperature extremes, electrical transients, direct solar radiations, cosmic radiations, vacuum, micrometeoroids...)

   (d) Operating lifetime and shelf life

   (e) Telemetry requirements

   (f) Special mechanical requirements (e.g., deployment on a boom, opening and closing of shutters, insertion and removal of filters and/or calibration sources, periodic changes of attitude and/or configuration, alignment...)

TABLE IX

LIST OF SCIENCE EXPERIMENTS CONTAINED IN CATALOG

Discipline	Experiments
I Astronomy	I-A Ultraviolet and Infrared Emission of Stars (D. G. Marlow)
	I-B Mapping of Galactic Structure in Infrared and Ultraviolet (D. G. Marlow)
	I-C 0.75 to 10 Mc Galactic Radio Noise (R. Hertel)
II Solar Physics	II-A Ultraviolet Imaging of Solar Flares (D. G. Marlow)
	II-B Search for Solar Neutrons (C. Black)
	II-C Detection of Low Energy Gamma Radiation (C. Black)
	II-D Solar Coronagraph (D. G. Marlow)
	II-E Study of Temporal Variations in Solar Ultraviolet Emissions (M. W. Holm)
	II-F Infrared Emission from the Sun (D. G. Marlow)
	II-G Search for Characteristic X-Ray Emission from the Sun (C. Black)
	II-H Monitoring of Solar X-Ray Emissions in the Region of 0.2 to 24 keV (C. Black)
	II-I Extreme Ultraviolet Spectrum of the Sun (L. M. Snyder)
	II-J Profile of Solar Lyman Alpha (R. Anderson)
III Particles and Fields	
	III-A Spectra of Galactic Electrons (R. Hertel)
	III-B Study of Earth's Albedo Neutrons (C. Black/J. H. Mullins)
	III-C Intensity and Abundance of Light and Medium Nuclei in Galactic Cosmic Radiation (R. Hertel)

TABLE IX (contd)

Discipline	Experiments
	III-D Trapped Particle Experiment (A. Y. Yahiku)
	III-E Detection of High-Energy Galactic Gamma Radiation (C. Black)
	III-F Proton Dosimeter (R. Hertel)
	III-G Search for Key Galactic Gamma Radiation (C. Black)
	III-H Spectrum and Flux of High-Energy Galactic Protons (T. T. Samaras)
	III-I Low-Energy Proton Spectrometry with Differentially Shielded Solar Cells (B. Ross)
	III-J Satellite Charging and Discharging Characteristics (R. Hertel)
	III-K Ionization Chamber Experiment (T. T. Samaras)
IV Planetary Atmospheres	
	IV-A Measurements of Earth Ultraviolet Radiation Flux (D. G. Marlow)
V Ionospheres and Radio Physics	
	V-A Topside Sounder (R. Hertel)
	V-B Investigation of the Composition of the Upper Atmosphere (R. Hertel)
VI Planetology	VI-A Photon Emission from the Dark Areas of the Moon (D. G. Marlow)
	VI-B Earth Albedo (D. G. Marlow)
	VI-C Ultraviolet and Infrared Lunar Albedo (D. G. Marlow)
	VI-D Physical Analysis of Micrometeoroids (L. M. Snyder)
	VI-E Effect of Hypervelocity Impacts on Structural Surfaces (L. M. Snyder)
	VI-F Chemical Analysis of Carbonaceous Meteoroids (L. M. Snyder)

TABLE X. ENGINEERING EXPERIMENTS

Technology		Experiment
I Power	I-A	Solar Cell Angle of Incidence Experiment
	I-B	Optical Transmittance Test
	I-C	Measurement of Reflective Surface Degradation
	I-D	Heat Pipe Experiment
	I-E	Concentrator Temperature and Strain Measurements
	I-F	Concentrator Reflectance and Angular Error Measurement
	I-G	Solar Cell Calibration Test
	I-H	Solar Constant of the Sun
	I-I	Measurement of Spectral Distribution of Space Sunlight
	I-J	Evaluation of Conventional Batteries in Zero Gravity
	I-K	Evaluation of Regenerative Hydrogen-Oxygen Fuel Cell in Zero Gravity
	I-L	Radiation Effects on Solar Cells*
	I-M	Vee-Ridge Photovoltaics*
	I-N	Thin Film Solar Cells*
	I-O	Solar Thermionics*
	I-P	Pyrometer
II Attitude Control	II-A	Brushless dc Torquer - Reaction Wheel
	II-B	Attitude Control by Electric Thrustors
III Thermal Control	III-A	Thermal Control Phase Change Materials
	III-B	Thermal Coatings*

*GE Final Report

TABLE X. ENGINEERING EXPERIMENTS (contd)

Technology		Experiment	
IV	Mechanical	IV-A	Cold Welding in Integrated Space Environment
		IV-B	Sublimation of Materials in Space
		IV-C	Meteoroid Armor Test
V	Telecommunications	V-A	Laser Experiment*
VI	Optical	VI-A	Transmittance Test
VII	Supporting Science	VII-A	Solar Ultraviolet
		VII-B	Solar Lyman Alphas
		VII-C	Proton-Electron
		VII-D	Solar Gamma Ray
		VII-E	Solar X-Ray
		VII-F	Micrometeoroids Pressure
		VII-G	Magnetic Field
		VII-H	Local Pressure

*GE Final Report

5. REPRESENTATIVE SPACECRAFT

Several groupings of experiments were conceptually placed on the spacecraft as being representative of the flexibility of the spacecraft. These representative spacecraft are discussed in Volume IV.

A typical payload is illustrated in Fig. 5, and consists entirely of engineering experiments in the power technology discipline and supporting science. Conceptual layouts of the secondary deployed panels of the spacecraft and the experiment equipment bays are shown in Figs. 6 and 7.

A summary of the weight, power and data requirements for the experiments chosen on payload No. 1 is given in Table X.

Payload No. 1 is only one of a large number of possible payloads. It illustrates several points which apply to all payloads investigated:

1. The spacecraft can contain a large number of experiments which can be relatively complex.
2. The available data-handling capability is considerably greater than required.
3. All of the experiments can be designed or placed in such a manner that the prime solar-thermionic experiment offers no interference.

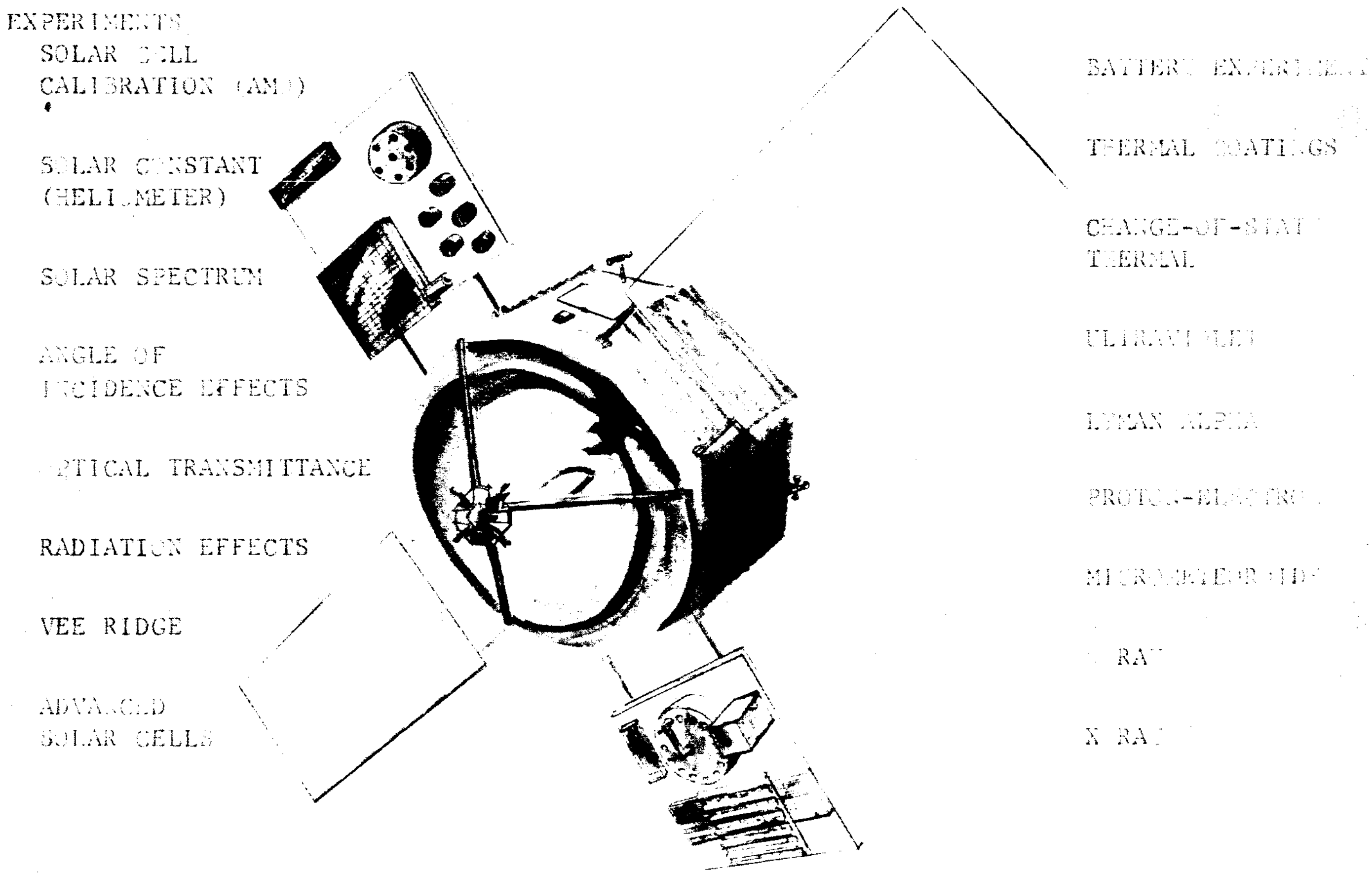
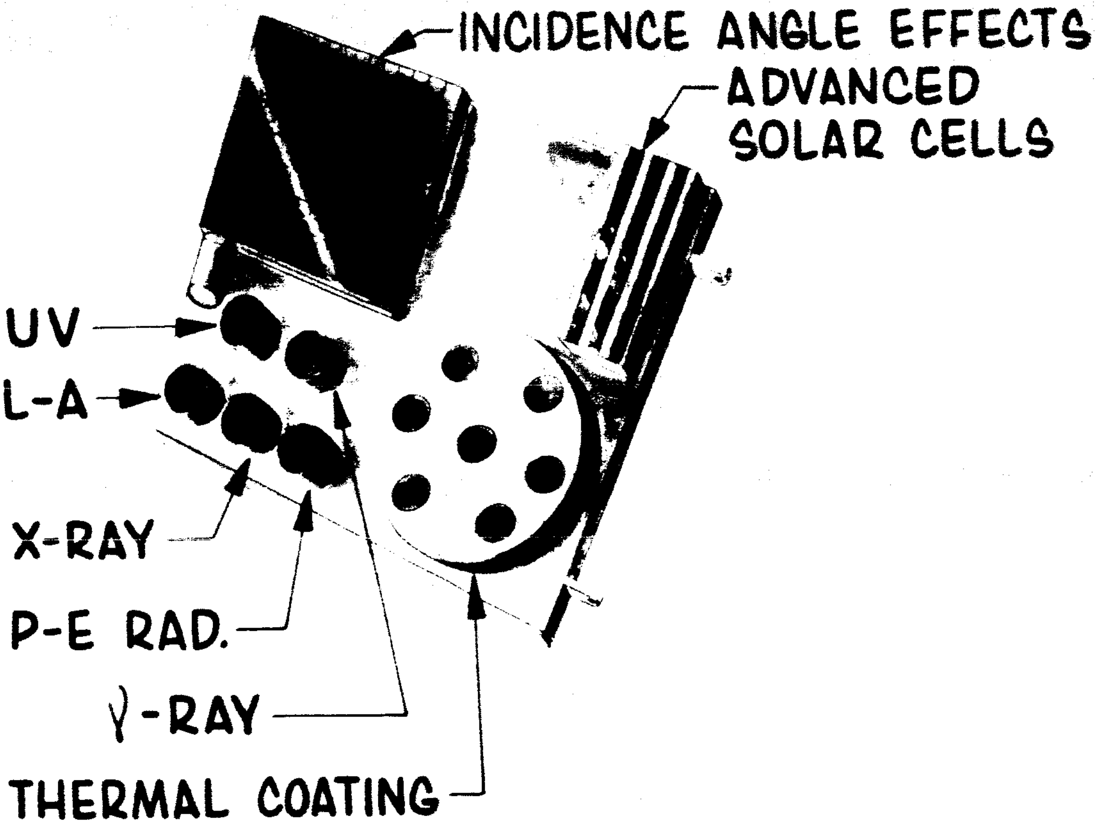


FIG. TYPICAL POWER TECHNOLOGY PAYLOAD NO. 1



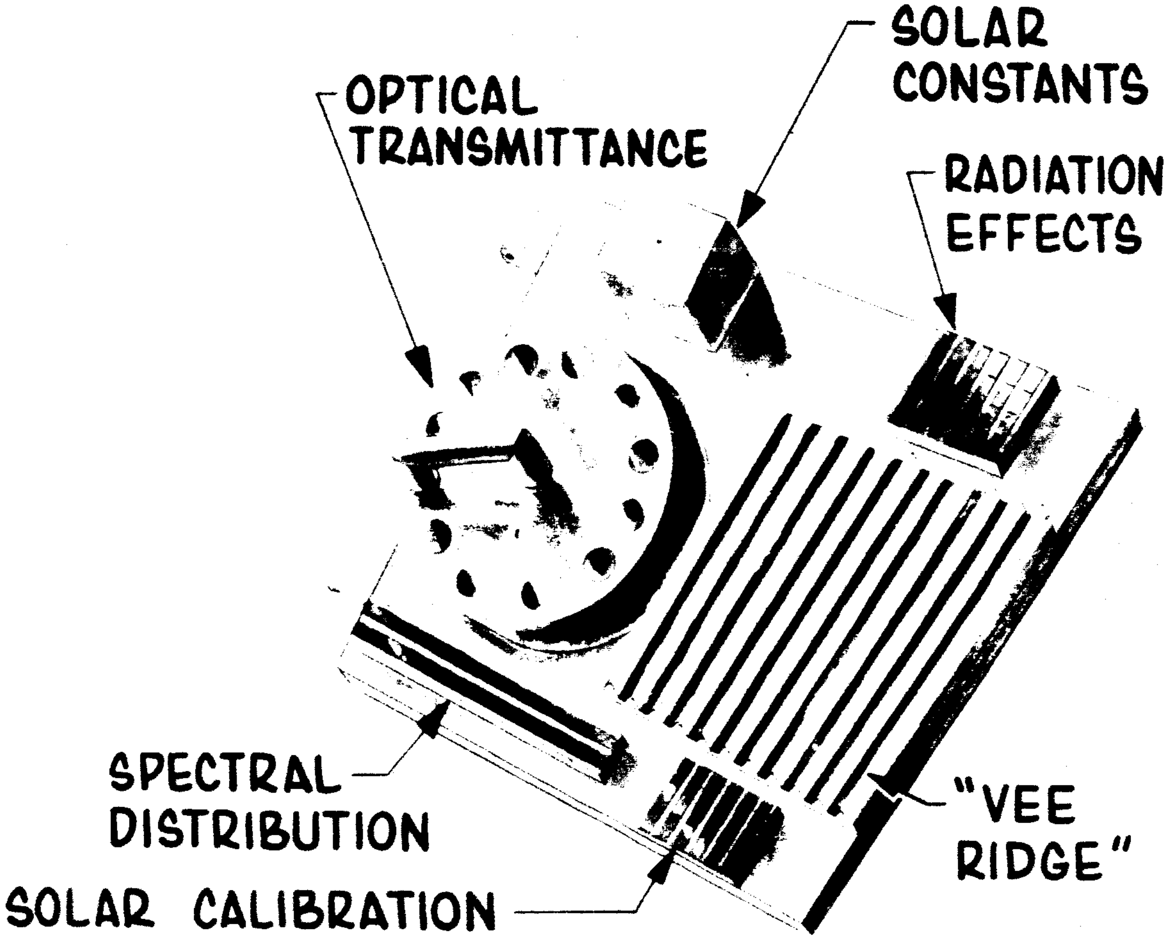


FIG. 6 SECONDARY PANELS PAYLOAD NO. [illegible]

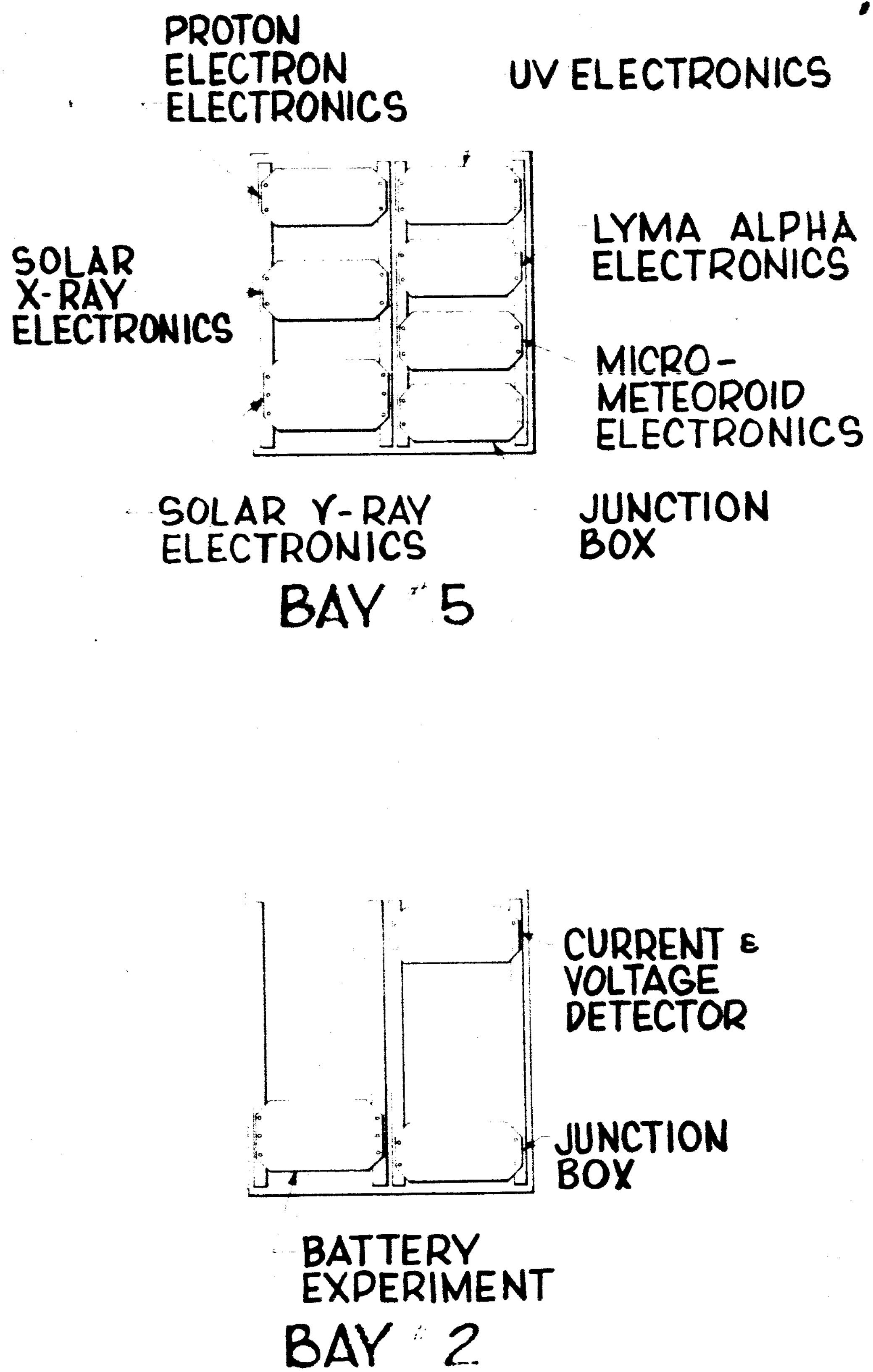


FIG. 7 EXPERIMENT EQUIPMENT BAYS

TABLE X

SUMMARY OF EXPERIMENT PARAMETERS-PAYLOAD NO. 1

	Weight Pounds	Power	Bits/Orbit
Primary Power			
Solar Cell Calibration (AMO)	1.5	0.2W 20 Min	216
Solar Constant (Heliometer)	2.5	1.5W 40 Min	96
Solar Spectrum	1.5	0.3W 10 Min	336
Angle of Incidence Effects	3.5	0.5W 10 Min	300
Optical Transmittance	15.0	8.0W 14 Min	252
Radiation Effects	0.5	0.1W 10 Min	108
Vee Ridge	2.0	0.2W 10 Min	224
Advanced Solar Cells	6.5	0.1W 10 Min	156
	27 lbs	2W Average	~ 1800 Bits
Secondary Power			
Battery Experiments	10 lbs	5W	1000 Bits
Thermal			
Thermal Coatings	2	0.2W 10 Min	96
Change-of-State Thermal	1	0.2W 10 Min	48
	13 lbs		~ 1150
Supporting Science			
Ultraviolet	2 lbs	2 watt	2160
Lyman Alpha	6	2 watt	540
Proton-Electron	8	3 watt	4470
Micrometeoroids	8	2 watt	96
Y Ray	8	4 watt	4470
X Ray	3	1 watt	149[illegible]
	35 lbs		13,240
Cabling + Junction Box + Contingency	6 lbs	-	-
Total	81 lbs	21 watts	~ 16,190
Allocated	83 lbs	20 to 30 watts	101,000